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Gastight Fabrics—FOR USE IN FUMIGATING WITH HYDROCYANIC ACID GAS

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Gastight Fabrics—

FOR USE IN FUMIGATING WITH HYDROCYANIC ACID GAS

By A. W. Cressman and H. R. Yust,[1] *entomologists, Entomology Research Branch, Agricultural Research Service,*[2] and D. Eichorn, *Flexfirm Products, El Monte, California*

Before the development of suitable synthetic plastics, rubber-coated fabrics had limited use in fumigation to free commodities of insect pests. One of the most important early applications of insecticidal gases was fumigation of citrus trees with hydrocyanic acid gas, and rubber-coated fabrics were early tested by Quayle and Knight (*6*) [3] in efforts to find a gastight tree cover for citrus fumigation work. Materials were unsatisfactory, mainly because the coating hardened, cracked, and became permeable to gas with age and exposure to weather, and citrus fumigators continued to use porous canvas tents.[4] As new plastic-coated fabrics became available, research to find a suitable gastight cover for citrus tree fumigation was reopened (Lindgren and Dickson (*5*), Fulton and Nelson (*3*)). While these studies were underway it became apparent that hydrocyanic acid gas fumigation of deciduous trees under gastight tents was the most promising treatment for eradication of Hall scale, a foreign insect that had been found in the vicinity of Chico, Calif., (Fosen, Cressman, and Armitage (*2*)). Findings at the Whittier, Calif., laboratory of the Entomology Research Branch were applied in the Hall scale project to improve procedure there, and that project, in turn, provided an excellent testing ground for new materials under practical field conditions.

Gastight tents never found acceptance in citrus insect control for two principal reasons—lack of any economical way to remove residual gas to insure safety of workmen, and development of insecticides and methods that displaced fumigation. However, gastight fabrics are widely used in other fields. Increasing attention is being given to fumigation of stored grain and other products to prevent destruction by insects. Commodities and equipment are fumigated for movement under quarantine regulations. Fumigation of houses and other buildings for control of various household and stored-product insects is another expanding field that demands a gastight fabric that is strong and light and will resist deterioration by aging and exposure to sunlight and weather (fig. 1). In the Hall scale project, fumigation of trees covered with such materials gives promise of eradicating this insect in the United States (fig. 2).

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[1] Now with Foreign Operations Administration.

[2] R. A. Fulton, of the Entomology Research Branch, contributed to the early phases of the work. Gas concentrations in the Hall scale fumigation were determined by H. J. Crawford, of the former Bureau of Entomology and Plant Quarantine.

[3] Italic numbers in parentheses refer to Literature Cited, p. 14.

[4] A fumigation tent is an octagon-shaped piece of fabric with metal rings for attachment to equipment used in moving the tent from tree to tree.

This circular summarizes the investigations of the Whittier, Calif., laboratory in developing a gastight fabric suitable for tree fumigation with hydrocyanic acid gas, and experience with selected fabrics in Hall scale fumigation. Many of the properties that are necessary for a material that is to be used in fumigation of trees should be desirable in other applications. For work with other gases, impermeability and stability to the chemicals to be used would need to be established.

PHYSICAL PROPERTIES AND TESTING METHODS

Some of the materials examined were procured already coated, but in other cases cloth was purchased and then coated by different firms in an effort to obtain a product with the special properties required. Characteristics of both coated and uncoated cloths were important. Properties of uncoated cloths that were considered included weight, breaking strength, tearing strength, flexibility, and weave. Properties of the coated fabrics included the first four of these characteristics and also permeability to air or hydrocyanic acid gas, adhesion of the coating, abrasion resistance, effect of aging and exposure to weather, and stability in the presence of hydrocyanic acid gas.

Strength and weight were determined by appropriate methods under Designation: D 39 of the American Society for Testing Materials (*1*). Breaking strength was measured by the grab method, and tearing

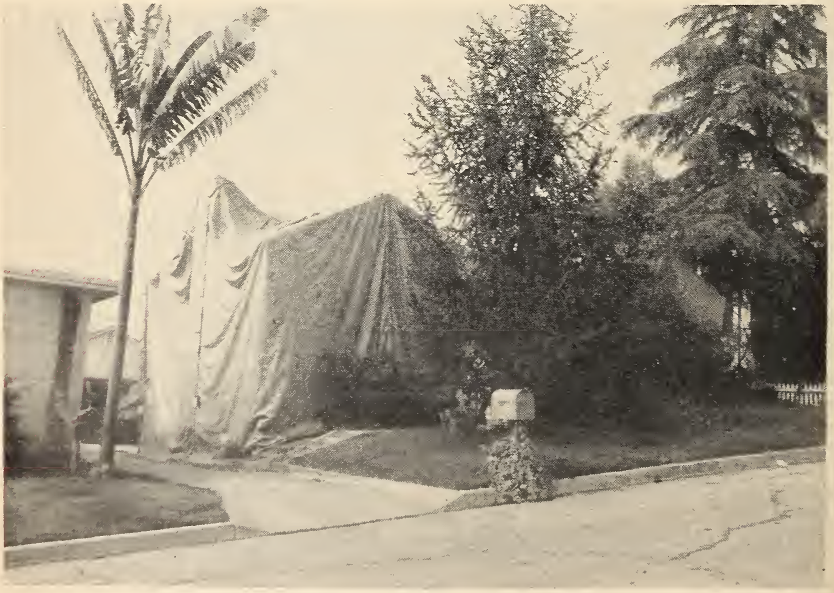

FIGURE 1.—Fumigating a house to control insects.

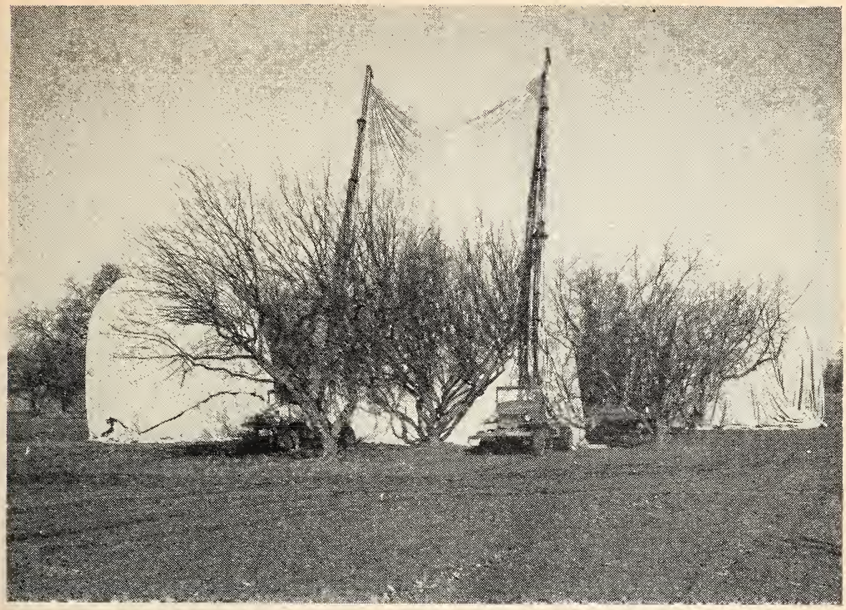

Figure 2.—Fumigating almond trees infested with Hall scale.

strength by the tongue method. Acceptable standards of strength and weight obviously will be determined by the use for which the cloth is intended. Experience showed that for fumigation of deciduous trees, tearing strength of the coated cloth should be at least 8 pounds in warp and filling. Any materials meeting this standard had adequate breaking strength. The uncoated cloth should have a greater tearing strength than 8 pounds since there is always some loss in coating. The yarn of an uncoated fabric can slip and shift under tearing stress, yielding higher tearing strength than the coated fabric on which the continuous film of plastic reduces movement of the individual strands. The loss in tearing strength resulting from coating varied with the type of cloth, the coating material, and procedure. In one case, coating caused a 50-percent decrease. Breaking strength was improved by addition of the plastic.

A weight of about 8.5 ounces per square yard of coated fabric was best for the Hall scale fumigation. If fabrics were much lighter than this, wind interfered too much with moving the larger tents from tree to tree and with covering the trees; increase in weight above 8.5 ounces per square yard gave little benefit in resistance to wind and greatly increased difficulties in manual handling and moving of tents. Somewhat lighter and weaker materials would have been acceptable for citrus.

The type of weave is one of the factors affecting the relative warp and filling strength and the smoothness of finish of the uncoated cloth. A plain weave with yarns which give approximately equal warp and filling strength is desirable. Too open a weave is objectionable because the plastic required to fill in the interstices increases the weight. A tight weave and smooth finish requires less coating to seal the fabric, and hence permits a lighter weight finished material. Even yarn tension during weaving is necessary to produce a fabric without sections that will sag during coating operations. Heavy deposits of plastic may be formed in such areas. Difficulty of this kind is encountered more often with cloths woven of synthetic yarn than with cotton fabrics.

Flexibility is needed in rolling and folding the tents, and to permit smooth draping over the trees and folding at the ground in order to minimize gas leakage at this point. None of the uncoated fabrics were too stiff except some nylon that had been highly calendered to reduce permeability. Calendering of nylon cloth before coating is unnecessary. The degree of stiffness required in the coated cloth was determined by field use of a large number of materials, and subsequent samples were rated largely by personal judgment and comparison with fabrics known to be satisfactory. An objective measure of flex-stiffness of some materials was made by the directional hanging-heart loop method (7) for testing textiles to meet Federal specifications. A coated cloth with stiffness of 1.7 inches warpwise and 2.0 inches filling-wise was much too stiff to be usable. One with stiffness of 2.5 inches warpwise and 2.4 inches filling-wise was usable but with some difficulty, particularly on small trees where there was much tent material to be kicked in at the edge. Two fabrics that were quite satisfactory had stiffnesses of 2.8 and 3.0 inches warpwise, and 2.7 and 3.0 inches filling-wise, respectively.

Abrasion resistance and adhesion are two related properties. Resistance to abrasion depends on both the toughness of the coating and adherence between coating and cloth. In use, tents were subjected to abrasion from dragging over rough ground that was sometimes frozen, to scratching and cutting action from fruit spurs and sharp ends of pruned and broken tree branches, and to being walked on when lying on rough surfaces. No mechanical tests were devised to adequately simulate this type of wear. After a material was found that proved satisfactory in abrasion resistance in field use, later candidate materials were compared with it by various rather subjective methods such as scratching with a needle with flattened end. Adhesion was also important with smooth fabrics such as nylon. Some formulations that formed a tough film peeled from the cloth when adhesion was poor.

Stability toward hydrocyanic acid gas was checked by placing a piece of the test material in a desiccator containing enough liquid hydrocyanic acid to saturate the air. After one week the sample was examined for signs of reaction such as softening or hardening of the coating or discoloration.

Permeability to air was measured in the laboratory with an apparatus as shown in figure 3. An inverted open cylinder (B) floating in oil inside of another cylinder (C) forces air through an axial tube (D) extending above the oil level, and creates air pressure against the test materials. A weight (A) sufficient to give a pressure of 2.25 inches of water (measured by the manometer (H)) with the air outlets closed, is put on top of the inner cylinder. The holder (G) for the test fabric is an osmometer such as that sold by instrument supply houses for classroom demonstration of osmosis. In making a test, two pieces of fabric 3 inches square (F) are clamped in the osmometer, with the air

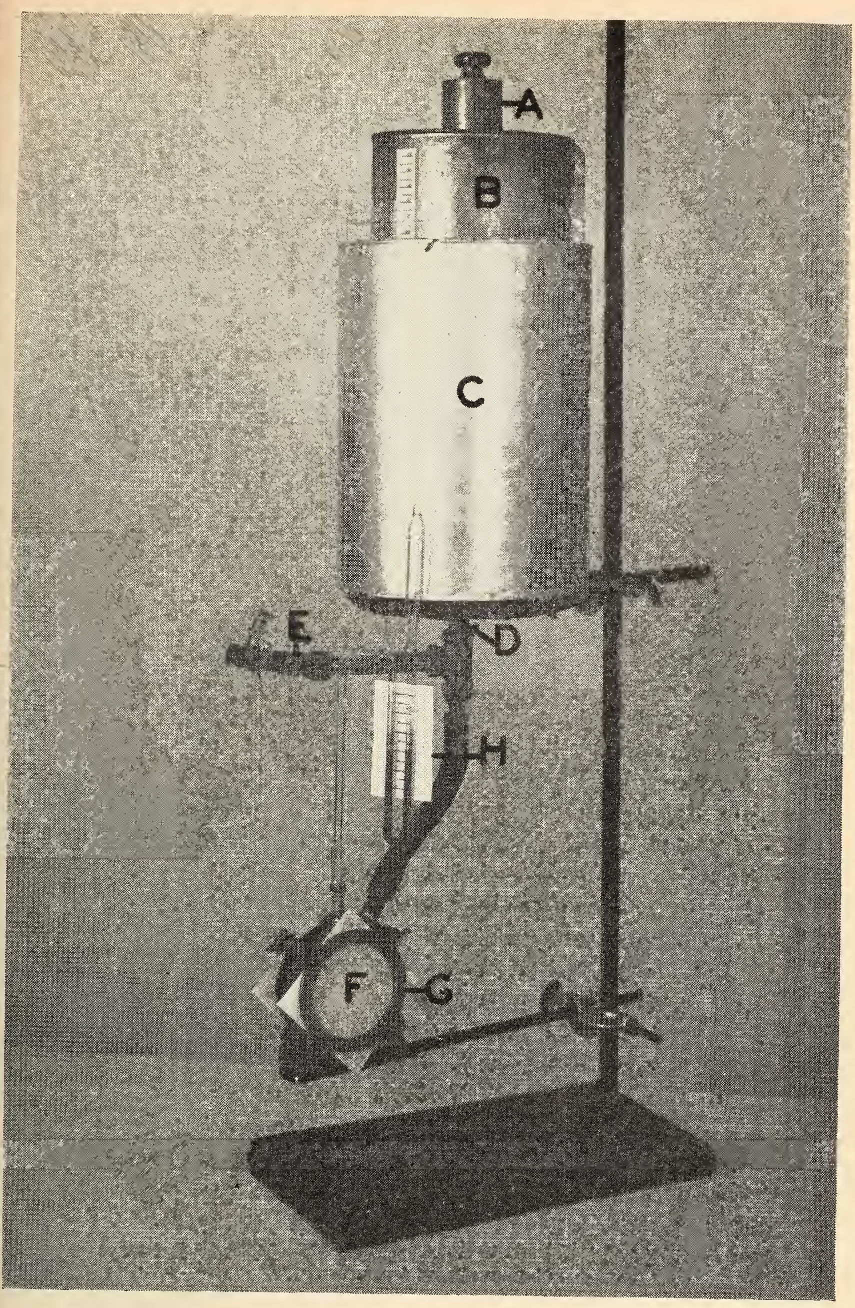

FIGURE 3.—Permeability meter.

bypass (E) open, the inner cylinder is raised, the air bypass is then closed, the cylinder released, and the rate of fall measured. The principle is similar to that of the instrument described by Haven (*4*), but the apparatus is made of materials generally available at a laboratory and permits testing a larger sample. The permeability of an area of 8.7 square inches of material is measured. Tests were made at room temperature and humidity. Temperature was usually between 70° and 75° F.

Permeability to air was found to be a good index of permeability to hydrocyanic acid gas. Most coated fabrics that had a measurable permeability before use or exposure tests showed a rather rapid increase when tried in the field, and in the latter part of the work field testing was limited to materials that showed no permeability under conditions of this test.

Stability to aging and weather was tested in three ways: (1) Outdoor exposure, (2) accelerated weathering, and (3) field use.

Outdoor exposure tests.—Specimens of cloth were placed on racks facing east at an angle of 45° on the roof of a building in full sun at the Whittier, Calif., laboratory.

Accelerated weathering test.—Two 3-inch-square samples of each material were placed in a weatherometer having double-carbon arcs in quartz globes, with water spray for 3 hours of each 24. Several different machines were used with some variation in conditions. Changes in the duration of the wet and dry periods in each cycle had little effect on the response of the samples, but raising the temperature from 104° to 155° F. accelerated changes. Hardness of water had some influence. In one instrument where untreated hard water was used, salt deposits formed an intimate bond with some coatings and caused them to stiffen and then crack on flexing.

Materials in use are subjected to considerable creasing and folding, and coatings that stiffen with age may break and become permeable with such handling. In order to check this effect of weathering, some samples, after exposure, were examined at room temperature as follows: The test sample was laid over an upright cylinder, 4 inches high, with open ends and an inside diameter of 0.75 inch. The sample was pushed into the cylinder with a rod one-fourth inch in diameter applied to the center of the sample. The cylinder was then inverted, the bottom held on a solid surface, and the sample pressed against this surface by means of a flat-end rod 0.72 inch in diameter pushed down inside the cylinder with a force equal to a weight of 60 pounds. The sample was then removed from the cylinder and the operation repeated with surfaces of the sample reversed. Permeability to air was then measured. Some exposed samples were very permeable before this treatment and were not checked further.

Field use.—A limited amount of testing was done in citrus fumigation, but most experience was gained in the Hall scale fumigation. In the latter work, analyses of gas concentrations under the tents, 5 minutes and 40 minutes after the introduction of the hydrocyanic acid gas, were made at intervals during each year of use. From time to time samples were cut from some tents, and permeability to air determined in the permeability meter to correlate gas loss in the field with laboratory measurement. Considerable use was made of strip tests in which pieces of test material 1–22 yards long were sewed in tents. Permanence of the coating in field use depended not only on stability toward weathering but also on adhesion and on abrasion resistance. Visual inspection could often determine which factor was involved in breakdown.

A comparison of some results obtained by outdoor and weatherometer exposures is shown in table 1.

TABLE 1.—*Results of exposure tests of gastight tent materials in a weatherometer for 740 hours at 155° F., and on a roof from Dec. 5, 1949, to Aug. 30, 1950*

Sample No.	Material	Air permeability (cu. in./sq. in.)			
		Weatherometer exposure		Roof exposure	
		Flat	Crumpled	Flat	Crumpled
161	Aluminum organosol on cotton airplane cloth	0	0.09	0.20	0.50
162	Aluminum organosol on cotton sateen	0	.09	3.42	--------
163	Organosol top, solution base on nylon taffeta	10.68	--------	.09	.36
164	White solution resins on nylon taffeta	8.03	--------	2.22	4.53
165	Green organosol, 02249, on nylon taffeta	.07	.57	.02	.03
166	Yellow organosol, 02249, on nylon taffeta	0	0	0	0
167	Green organosol, 031849, on nylon taffeta	0	.11	0	.03
168	Organosol top, latex base on nylon taffeta	.10	.15	0	0
169	Green organosol on glass cloth	0	0	0	0
170	White and aluminum mixed solution resins on nylon taffeta	1.14	--------	.20	.77
171	Aluminum Fibrylon [1] coated glass cloth	0	0	0	0

[1] Trade names are employed only to identify a product. Their use does not constitute endorsement by the Department of Agriculture.

There were some differences in results by the two methods. Material No. 162 was poorest in the roof exposure test and one of the better in the weatherometer exposure. In the field, this material showed no leakage in 2 years' use. Tents then had to be withdrawn from regular fumigation because of weakness of the cloth. Material No. 163 was poorest in the weatherometer and intermediate in the roof exposure. Tents became permeable in the second year. Material No. 168 showed a slight permeability after weatherometer exposure. There was extensive buckling of coating from the cloth (probably because of poor adhesion) and the coating cracked in a few such places. This effect did not occur in the roof exposure. In the field where both weathering and abrasion occurred, there was much peeling and the material became quite permeable to gas in 1 year. In these materials, the weatherometer exposure was the better indicator of durability in the field. Two materials, Nos. 169 and 171, performed well in both exposure tests but failed in the field because of lack of abrasion resistance. Nos. 165, 166, and 167 performed relatively well in the exposure tests, and all were used for 5 years in the field. Tents made of material No. 167 showed a significant leakage at the end of the fifth season. No. 166 proved to be the best in the field and showed no leakage in the exposure tests. Its performance in the exposure tests, along with its adhesive qualities, resistance to abrasion, stability toward hydrocyanic acid gas, and other qualities, all indicated that it would be the best of the materials tested, and experience verified this conclusion.

Most of the materials that were examined were inferior to those listed in table 1 and became permeable in shorter exposures. Either weatherometer or roof-exposure tests were adequate to detect the instability of such coating.

FABRICS

The base fabrics used included various cottons, glass fiber cloths, and nylons. The strongest cotton cloth used in tents was 8-ounce U. S. Army duck. This weighed about 10 ounces per square yard before coating. In order to keep the weight down so that tents could be handled in the field, coatings had to be limited to 4 to 5 ounces per square yard. A very light coating was added to one side to give water repellency, and most of the plastic applied to the other side. Even with this procedure, the coated fabrics were not always gastight initially and none held up well in use. The weight made field operation difficult. Dividing the coating equally between the two sides was even less satisfactory.

Most of the cotton tents put into use were made of sateen. Somewhat less coating was required to seal the cloth than was needed for duck, but the strength-weight ratio in the finished material was still short of what was needed. Two weights of cloth, 8.4 and 6.2 ounces per square yard, were tried. Finished weights with the best coating obtained were 14.5 and 11.5 ounces, respectively. Tearing strength of the lighter material when newly coated was 5 and 3.5 pounds in warp and filling and was inadequate for tree fumigation.

Some tents were made of airplane cloth. This was woven of mercerized cotton yarn and calendered, resulting in a very smooth finish. A tight and durable coating on both sides was obtained with 4 ounces of plastic to give a finished weight of about 8 ounces per square yard. However, tearing strength in warp and filling was only 2 pounds, and tents had to be retired from regular use after one season because of tearing.

Other coated cotton cloths examined included drill, sheeting, poplin, bandolier cloth, and jean cloth. None of these had the necessary tearing strength for field use.

Most cottons required a rather heavy coating to seal properly against gas loss. Unless both sides were sealed, tents took on moisture in wet weather, thus increasing the weight. They then dried much more slowly than uncoated material. Not only did they lose tearing strength in coating but all of the coated cotton materials examined lost strength more rapidly in roof exposure tests than the same cloths uncoated. Because of these disadvantages, attention was given to other fabrics as they became available for civilian use after the war.

Glass fiber cloth is considerably stronger than cotton of similar weight and is not affected by rot or mildew. It is easily abraded, and even flexing of the cloth, which rubs the fibers against each other, may break the yarn. It was necessary, therefore, to apply sufficient coating on both sides to protect the yarn against surface wear and to penetrate the cloth sufficiently to surround the individual strands to prevent internal abrasion. This required 6 to 7 ounces of coating on a cloth weighing about 5.4 ounces per square yard. One tent was made of this material. With continued exposure to sunlight, abrasion, and flexing in the field, the threads or fibers tended to break through the plastic film, causing small holes in the cloth and increased permeability. The tent became unusable after 3 years in the field. Other coated glass cloths in strip tests broke down in equal or shorter times because of breaking of the fiber and lack of abrasion resistance when the protective coating was gone. No way to overcome this weakness was apparent.

Nylon cloth is less affected by flexing and creasing than glass fiber cloth, is also resistant to rot and mildew, and, when tightly woven of continuous filament yarn, has a smooth surface on which a small amount of plastic will form a continuous film. Because many plastic mixtures are not readily absorbed by the yarn, cloth can be coated with relatively little loss of tearing strength. For example, a cloth with tearing strength of 14 pounds when covered with our most commonly used coating lost only 2 to 3 pounds in warp and filling strength. Other coatings, less satisfactory in other respects, have been applied with even less effect, but some combinations of coating and cloth have resulted in somewhat more loss. The smoothness and nonabsorbency of the yarn made adhesion of coating to cloth a problem. Uncoated nylon is somewhat unstable to ultra violet light and loses strength on exposure to sunlight. However, a pigmented coating gives a high degree of protection against this effect. An uncoated nylon with an initial tearing strength of 14 pounds in warp and filling used in citrus fumigation lost about two-thirds of its strength in 2.5 seasons' use; a coated nylon with initial tearing strength of 12 and 10.5 pounds in warp and filling, lost only one-half its strength in five seasons' use in the Hall scale fumigation. The latter work is the more severe test of resistance to sunlight since it is done in the daytime and citrus trees are fumigated at night. Most of the nylons examined were in a plain weave with relatively little difference between warp and filling strength. This construction proved most suitable for fumigation covers. It seemed best to describe the tightness of weave by a permeability specification rather than yarn size and count. The cloths that proved satisfactory had air permeability, as measured by the calibrated orifice method (*7*), of less than 55 cubic feet per minute. Fabrics which were coated and tested in the field weighed between 3.75 and 4.25 ounces per square yard, and tearing strength was generally in the range of 13 to 17 pounds before coating. For less severe use a lighter cloth might be used with consequent saving in cost.

The possibility of using a rayon-nylon "rip-stop" fabric was examined. The cloth tested was a light rayon cloth reinforced with heavier nylon yarns at 0.5-inch intervals in warp and filling. Cost was less than for an all-nylon fabric and it was thought that the nylon reinforcing might give the needed strength. However, a thick coating was needed to cover the nylon threads, and differential shrinkage of the two yarns caused puckering that made the cloth unusable.

COATINGS

The first coated tent material was a mixture of polyvinyl butyral and melamine resins on muslin sheeting. The tent was initially gastight, and was light and flexible, and suitable for limited experimental work on citrus, although easily torn. Subsequently, several tents were made of the same coating on 2.50 drill, and used in the Hall scale fumigation. This material was stiff, and the plastic checked and cracked and became quite permeable by the end of one season.

Several rubber coatings on nylon were unsatisfactory because of poor adhesion. They all showed some deterioration and permeability after 164 hours in a weatherometer at 104° F. A similar result was had with a neoprene-coated nylon. Thiokol (a condensation product of sodium polysulfide with ethylene dichloride or other chlorine-containing derivatives) coating on nylon softened on exposure to hydrocyanic acid gas and was not tested further. A blend of acrylonitrile and polyvinyl chloride showed poor adhesion to nylon and stiffened and cracked on exposure in a weatherometer for 100 hours. A base coat of a solution of a maleic acid modified vinyl chloride-vinyl acetate copolymer, over which a blend of acrylonitrile and polyvinyl chloride was applied, improved adhesion but not resistance to exposure.

A large number of polyvinyl chloride coatings were tested. Lindgren and Dickson (*5*) reported that a sample of Koroseal showed little effect in a year's exposure to sunlight and weather, and fumigation tents showed no increase in gas loss after two years' use on citrus. The fabric base was airplane cloth, a material which was too light for deciduous tree fumigation. The manufacturer submitted several samples of coating on other materials. One on bandolier cloth was little affected by 100 hours of weatherometer exposure or 5 months' exposure on a roof. It was too weak a fabric for fumigation use. A 10-ounce coating on 8-ounce sateen cracked in the roof exposure, and a lighter coating on nylon also became permeable in this test. Adhesion to the nylon was poor. The materials with a cotton base were impregnated and were heavy relative to their strength. The first polyvinyl chloride used in field fumigations of deciduous trees was on duck and sateen. Tents failed to last one season in the Hall scale work. In fumigations in October 1946, the first month of use, the average loss of gas in 35 minutes was 32 percent, and in March 1947, 70 percent. A laboratory permeability reading on the new material was 0.02 cubic inches per square inch, and after use, from October until March, it was 5.33 cubic inches per square inch. After 50 hours' weatherometer exposure, permeability was 0.31 cubic inch per square inch, and after 164 hours, 10.66 cubic inches per square inch. A large number of samples of polyvinyl chloride and vinyl chloride-vinyl acetate copolymer coatings were prepared and tested in the laboratory. Solutions of copolymers of low and medium molecular weight in organic solvents with various plasticizers and stabilizers did not give satisfactory performance in the weatherometer or roof-exposure tests.

Polyvinyl chloride latex, an aqueous dispersion of resin and plasticizer, proved somewhat better for coating than the copolymer solutions in weatherometer exposures. Coating was applied as a dispersion and heated in a curing tunnel at 250°–275° F. for 3½ minutes to remove water and form a film. A coated nylon was gastight after 400 hours' exposure in a weatherometer, but showed a permeability of 2.13 cubic inches per square inch after 685 hours. The base fabric had some effect on its lasting qualities since a similar coating on airplane cloth had a permeability of 2.56 cubic inches per square inch after 400 hours' exposure. The difference may have been due to greater absorption of the plastic by the cotton fiber and a consequent thinner film. A strip test in a fumigation tent was made of the latex coating with aluminum pigment on nylon. It failed in one season's use because of poor resistance to abrasion.

A better coating was obtained with an organosol-type mixture, a dispersion of vinyl chloride-vinyl acetate copolymer of high molecular weight in mixed phthalate and phosphate plasticizers and organic diluents. After application of the coating the fabric was run through a curing tunnel at a temperature of 325°–350° F. for 3 minutes to fuse the resin particles and form a film. Pieces of cotton sateen covered with one base coat of vinyl latex resins on each side and two coats of the organosol dispersion on one side were not affected by 300 hours in the weatherometer. The vinyl latex undercoat was used to apply a film on the surface of the fabric and reduce penetration into the cloth. Latex dispersions tend to separate when applied to cotton fabrics leaving the solids on the surface. Water is absorbed into the cloth and subsequently evaporated by heat. A number of fumigation tents coated with the latex and organic dispersion combination were made up for the Hall scale fumigation. After treating with a mixture of chlorophenyl phenols for resistance to mildew, plastic at the rate of 6 ounces per square yard was applied to an 8.4-ounce cotton sateen. Tents were still nearly gastight at the end of the third season when the cloth became too weak for further use. The same material gave a laboratory permeability reading of 0.02 cubic inch per square inch when new, and 0.2 cubic inch per square inch after 831 hours in a weatherometer. This was the most durable coating yet obtained, but the material was unsatisfactory because of its weight and lack of strength.

An attempt was therefore made to develop a means of applying this coating to nylon. It was found that nylon was not measurably injured by the curing conditions required. However, adhesion of the plastic was very poor. It was improved somewhat by applying a base coat of vinyl latex with the organosol dispersion over this, but was still inadequate for field use. Coating peeled in numerous spots from the nylon strip in a fumigation tent in one season's use. The vinyl chloride-vinyl acetate copolymers of low molecular weight adhered fairly well to nylon. When such resins were used as a priming coat with an organosol top, resistance of the combination to exposure was relatively poor. Permeability after 740 hours in a weatherometer at 140° F. was 10.66 cubic inches per square inch. Material tried in the field became permeable in the second year's use. Evidently the combination of the two resins caused the high-molecular-weight polymer to break down more quickly.

Various adhesives were then tested. Some of these reacted with the vinyl chloride-vinyl acetate coating to cause deterioration in prolonged weatherometer tests, but two mixtures of phenolic resins and acrylo-nitrile butadiene showed promise. The adhesives differed in the proportion of phenolic resins in the mixture. Nylon was coated with one of these and then with the organosol dispersion in two colors, chrome yellow and phthalocyanine green pigment (No. 02249). A coating with the other mixture was made up in green only (031849). From 4 to 4½ ounces of coating, about 60 percent on one side, was applied to a 4-ounce nylon. Samples were exposed in a weatherometer at 155° F. for 740 hours, and on a roof at Whittier from December 5, 1949, to August 30, 1950. Permeability tests were also made after 5 years' use in the field. Results are given in table 2.

TABLE 2.—*Results of permeability tests of coated nylon in a weatherometer, roof exposure, and 5 years of field use*

Material	Permeability to air (cubic inch per square inch)		
	Weatherometer exposure	Roof exposure	Field use
02249 Yellow	0	0	.10
02249 Green	.57	.03	.29
031849 Green	.11	.03	.43

Test material 02249 in yellow was the best of the three coatings in both weatherometer and roof exposures, and held up best in field use. The same coating except with green pigment was slightly less durable. There was little consistent difference between the two coatings in green. Both developed a slight permeability in the roof test. Material 031849 was less affected by the weatherometer exposure, but became a little more permeable in field use. The tent showed the effects of abrasion more than tents of the other two materials. Gas samples were taken in two tents during fumigations in the 1953–54 season, the fifth year of use. Average gas loss in the tent made of 02249 yellow was 10 percent, and of 031849, 21 percent. The first loss is within the range found in tents known to be gastight, and is due mainly to sorption by tent, tree, and ground, and perhaps a small leakage at the edges. A measurable amount of gas was being lost through the second tent, although not enough to be important in routine fumigation. A number of tents of both coatings with yellow pigment were put into use in the fall of 1950. During the fourth season of use the average gas losses in 35 minutes were 11 percent for 031849, and 14 percent for 02249, a nonsignificant difference. Both coatings made serviceable materials and no difference between them was apparent in 4 years' use.

MISCELLANEOUS FACTORS

Choice of pigment may affect the qualities of the coating and cloth, but relatively few pigments have been compared. A difference between a green and a yellow was noted above. Aluminum has both advantages and disadvantages. It made more flexible materials and caused less loss of tearing strength than some other coatings. An extreme example of this was noted in a glass fiber cloth coated with an organosol dispersion with phthalocyanine green and aluminum pigments. The green material had tearing strengths of 10.5 and 9.5 pounds in warp and filling, the aluminum, 17 and 16 pounds. The aluminum coatings were generally softer and had less abrasion resistance than white titanium dioxide, chrome yellow, phthalocyanine green, and some other colors.

In applying coatings it was better to apply several thin layers than one heavy coating. Small bubbles form in the plastic during the coating, and when the surface film breaks, minute holes are left. If several coats are applied, "pinholes" will seldom extend through the whole coating.

RECOATING TENTS

One of the problems encountered was that of refinishing tents that became permeable to gas early in their use. The mixture finally developed was a solution of mixed vinyl chloride and vinyl acetate copolymers in methyl ethyl and other ketones with plasticizers and pigment. The material was applied by brush since spray applications left too many air bubbles. A better application was obtained with aluminum pigment than with cadmium red, cadmium orange, or phthalocyanine green. Cyclohexanone was a satisfactory thinner. Tents were air dried after treatment. The mixture was used on several polyvinyl chloride coatings on cotton, and on the vinyl chloride-vinyl acetate copolymers on nylons. About 1 ounce of coating per square yard was needed to seal. Tents refinished in this way remained gastight or nearly gastight for 1 to 2 years. The mixture did not adhere well to the polyvinyl butyral-melamine coating on cotton (p. 10), and the coating of organosol dispersion over vinyl chloride-vinyl acetate copolymers of low molecular weight on nylon (p. 11) was softened and loosened from the cloth by the mixture. Both these materials had to be discarded when they became permeable to gas.

SUMMARY

Plastic-coated gastight fabrics for fumigation of trees with hydrocyanic acid gas were developed at the Whittier, Calif., laboratory of the Entomology Research Branch. These fabrics may be useful in other fields.

Important physical properties were strength, weight, weave of the base cloth, flexibility, abrasion resistance of the coating, adhesion between cloth and coating, permeability, and stability to aging and weathering.

A tearing strength of 8 pounds in the finished material was adequate for deciduous tree fumigation. Strength of the uncoated cloth should be greater since there is always some loss in coating. The ideal weight was about 8.5 ounces per square yard. Weaker and lighter materials might be suitable for other uses.

Abrasion resistance depended on both the toughness of the plastic film and adhesion between coating and cloth. Good adhesion was necessary to prevent peeling of coatings from smooth fabrics.

Instability toward aging and exposure to weather was reflected in increasing stiffness and permeability. Many materials that were initially gastight deteriorated rapidly on exposure. This property was checked by roof exposure and weatherometer tests of candidate materials, followed by tests of permeability.

Cotton cloth required a rather heavy coating to seal it against gas loss, and the strength-weight ratio was unsatisfactory for field use. Glass fiber cloth was superior to cotton in some respects but the physical properties of the glass fiber made the coated material break down after several year's use. Advantages of nylon cloth included strength, resistance to rot and mildew, and ease of sealing with a light coat of plastic. The effect of sunlight on nylon was decreased by coating.

A dispersion of vinyl chloride-vinyl acetate copolymers of high molecular weight with mixed phthalate and phosphate plasticizers on nylon cloth made the most satisfactory fabric. An adhesive was necessary to bond coating and cloth. Fumigation tents of this material remained gastight or nearly gastight through 5 years of use. Copolymers of lower molecular weight, and various polyvinyl chloride and other plastic coatings were less durable.

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